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FORECASTING WET MICROBURST ON THE CENTRAL FLORIDA ATLANTIC COAST IN SUPPORT OF THE UNITED STATES SPACE PROGRAM

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1. INTRODUCTION

This paper describes the new wet microburst forecasting techniques developed and implemented by the Applied Meteorology Unit (AMU) and the Air Force's 45th Weather Squadron (45th WS) in support of the U.S. Space Program at Kennedy Space Center (KSC) and the Eastern Range (ER). The 45th WS is responsible for all meteorological support to ground and space launch operations for the 45th Space Wing. The AMU was created in 1991 as an interagency effort among NASA, the 45th Space Wing at Patrick Air Force Base and Cape Canaveral Air Station (CCAS), and the National Weather Service (NWS) (Ernst and Merceret 1995). Development of these microburst forecasting techniques was motivated by several strong, convective wind events that occurred at the KSC Shuttle Landing Facility (SLF) (See Figure 1 for map) on August 16, 1994. On this day, thunderstorms near the SLF produced wind gusts of 33.5 m s^{-1} (65 knots) which were much greater than forecast. Fortunately, there was no operational impact. The 45th WS suspected that a wet microburst was responsible for the unexpectedly high winds (Roeder 1994a). To confirm this hypothesis, the AMU analyzed synoptic and mesoscale meteorological data associated with this event and concluded that a microburst was indeed responsible for the strong winds observed at the SLF on August 16, 1994 (Wheeler 1994).

This event led the 45th WS to re-examine their severe thunderstorm forecasting procedures. The 45th WS concluded that their forecasting procedures did not adequately address microbursts, especially given the weather sensitivities of ground and space launch operations at KSC and CCAS. Subsequently, the AMU and the 45th WS developed and implemented new microburst forecasting techniques.

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2. BACKGROUND

Previous studies developed a rawinsonde model depicting the thermodynamic structure of a dry microburst for the High Plains (Wakimoto 1985). Wakimoto and Bringi (1988) showed that a different class of microbursts (wet microburst) exists for areas that have heavy convective rains. During the 1986 MIST (Microburst and Severe Thunderstorm) project conducted in northern Alabama, Atkins and Wakimoto (1991) captured data from several wet microbursts and documented the general environmental conditions that favor these events.

Examination of the thermodynamic structure of the atmosphere for the wet microburst days indicated it was possible to differentiate between normal thunderstorm days and microburst days by analyzing the vertical profile of equivalent potential temperature. By analyzing the difference between the surface value of equivalent potential temperature (θ_e) and the minimum value aloft, it is possible to estimate the microburst potential. Based on the data from the MIST project, Atkins and Wakimoto proposed that if the difference of the θ_e surface value and the minimum value aloft is greater than or equal to 20° K, then there is a high potential for a wet microburst occurrence. If the difference is less then 13° K, then wet microbursts are not likely.

During the analysis of Doppler radar data from the microburst events in the MIST project, Atkins and Wakimoto (1991) noted a nowcasting signature in the vertical storm structure. They observed that the height of the main precipitation core relative to the height of the minimum θ_e within the main storm structure is important to wet microburst. In all radar

observed wet microburst events this core (maximum reflectivity) consistently reached the level of minimum θ_e, and the upper portion of this core reached heights of 7 km (dry region above 500 mb). This upper core is made up of mostly ice.

3. CASE STUDY SUMMARY

On August 16, 1994 the KSC and CCAS area experienced several strong downrush wind events. The events started at 2000 UTC near the NASA causeway and moved east-northeastward across KSC by 2100 UTC. Figure 1 is a map of the KSC and CCAS area. The strongest wind gusts of 33.5 m s^{-1} (65 knots) were reported at the SLF between 2030 and 2050 UTC.

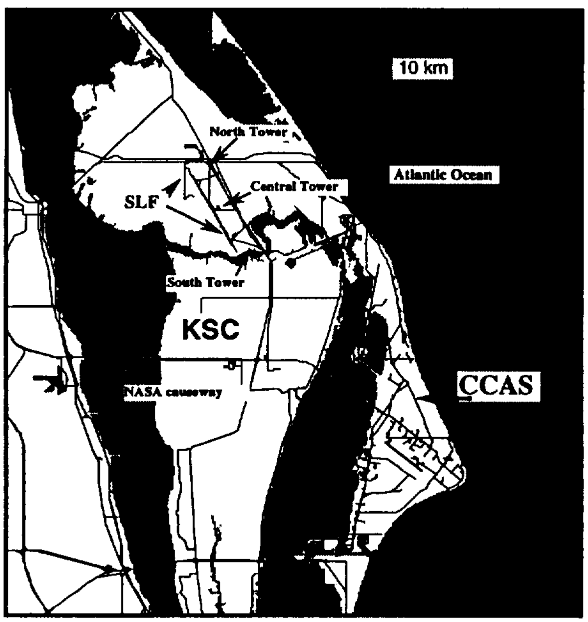

Figure 1. Map of KSC and CCAS, FL.

At least two of the local storms that day met the criteria experts (Fujita 1985 and Atkins and Wakimoto 1991) have established as microburst signatures. The equivalent potential temperature (θ_e) profile from the late morning rawinsonde sounding was characterized by a large decrease in the θ_e in the lowest 4.3 km (14000 ft) of the atmosphere. Figure 2 compares the θ_e profile from August 16, 1994 to a more typical thunderstorm day (no mircoburst) θ_e profile from August 10, 1994. The August 16, 1994 type of environment was conducive for the development of microbursts as shown by the large difference in θ_e between the surface and 590 mb.

Analysis of the WSR-88D radar reflectivity values showed the main precipitation core reached an altitude of 4.3 km (14000 ft), the level of the minimum θ_e aloft. These two analyses indicated that the local environment was conducive for microbursts based on the criteria developed from the MIST project in northern Alabama.

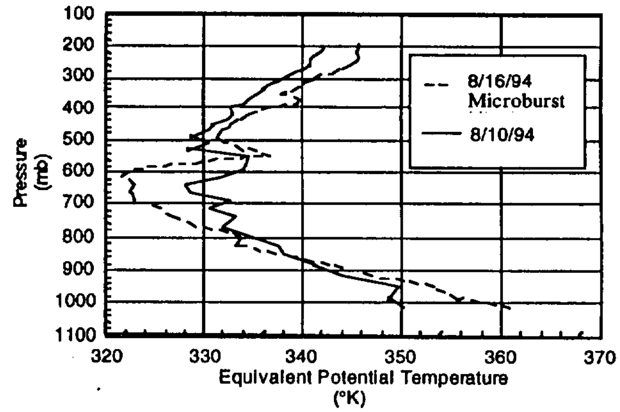

Figure 2. Thermodynamic profile of equivalent potential temperature for August 16 (microburst) and August 10, 1994 (non-microburst).

The wind plots for the north, central and south SLF wind sensors during the time of the microbursts (2030 and 2048 UTC) indicated a star-burst divergent pattern with a diameter less than 4 km (2.5 miles). Individual wind tower time versus wind speed profiles (Figure 3) were also similar to those Fujita found typical of microburst events (i.e. a mound-shaped appearance lasting 2 to 5 minutes) (Fujita 1985).

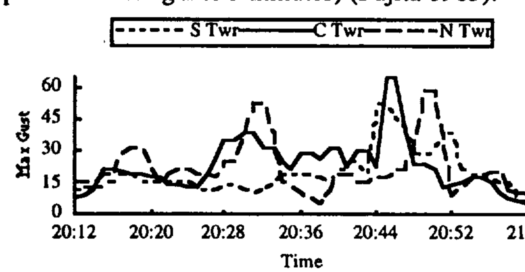

Figure 3. SLF wind sensor profiles between 2012 and 2100 UTC on August 16, 1994.

Analysis of the 1 minute wind data during the downrush event from each wind sensor shows the following:

- The north SLF wind sensor reported a shift to a more south-southwest flow (156° - 195°) with a gust of 30.4 m s^{-1} (59 kts),

- The center SLF wind sensor reported a wind shift of only 14° (184° - 198°) and a gust of 33.5 m s^{-1} (65 kts), and
- The south SLF wind sensor reported a more northwesterly shift in wind direction (246° - 279°) and a gust of 26.8 m s^{-1} (52 kts).

The reported winds exhibited a starburst (divergent) wind pattern at the SLF.

4. INITIAL VERIFICATION RESULTS

The 45th WS and AMU proposed a new Microburst-Day Potential Index (MDPI) based on θ_e profiles to indicate the likelihood of microbursts on a given day (Roeder 1994b). MDPI is designed such that values of 1.0 or greater suggest a high likelihood of wet microburst, assuming development of heavy precipitation.

MDPI = (Maximum θ_e - Minimum θ_e aloft)/ CT.

- Maximum θ_e = Maximum θ_e in the lowest 150 mb of the rawinsonde.
- Minimum θ_e aloft = Minimum θ_e between 650 and 500 mb.
- CT = Critical Threshold (30° K).

Because of the large surface temperature lapse on the early morning (1100 UTC) CCAS sounding and more tropical air mass (Central Florida vs. Northern Alabama), the Maximum θ_e was calculated using the lower 150 mb (Roeder 1995) and higher CT value. (Wheeler 1995). Both of these changes were modified locally from the work of Atkins and Wakimoto had done in the MIST Project.

Analysis of another similar microburst event at the Orlando International Airport (MCO) on July 27, 1994 added credibility in using the θ_e profile as a forecasting tool to microburst potential (Wheeler and Spratt 1995). During the MCO event a 32.95 m s^{-1} (64 kt) peak wind was recorded.

To verify the performance of MDPI as a categorical forecast for microburst potential at CCAS and KSC, data were archived from June 1 to August 31, 1995. Preliminary analysis indicated that there were a total of 28 possible microburst events in the CCAS/KSC area during that 3 month period. To determine the skill of the MDPI, a contingency table of MDPI versus observed conditions was developed (Table 1). The analysis consisted of first checking to see if the Range Weather Operations (RWO) forecaster had forecast and observed a thunderstorm at the SLF. If so, then a MDPI was computed. Archived wind sensor data were then analyzed for all days to check for peak wind speeds of 30 knots or greater. Besides helping in the microburst prediction, this would also highlight any non-predicated potential microburst events.

To be predicated YES the following criteria had to be met:

- Thunderstorm forecast and observed.
- MDPI of 1 or greater.

To be predicated NO, the computed MDPI was less than 1.

To be observed YES, winds of 30 knots or greater were observed on the local tower network (51 meteorological towers over a 900 sq. mile area).

To be observed NO, no wind greater than 30 knots was observed on the local tower network.

Table 1.

Predicated vs. Observed Microburst.

		Observed Microburst	
		No	Yes
Predicated	No	a 14	b 1
Condition	Yes	c 13	d 27

The following skill scores were calculated from the above data.

- Probability of Detection (d/b+d) POD = 96.4%
- False Alarm Rate (c/(c+d) FAR = 32.5%
- Critical Success Index (d/(b+c+d)) CSI = 65.5%

Using the MDPI to help forecast microburst potential does show good skill in alerting the RWO forecaster without giving an unreasonable false alarm rate.

For comparison, the skill scores were also computed based on the assumption that if the

forecaster predicted thunderstorms, then this is also a positive forecast for microbursts.

- Probability of Detection POD = 100%
- False Alarm Rate FAR = 57.6%
- Critical Success Index CSI = 44%

These results show that by using the MDPI as an additional qualifier (instead of assuming all thunderstorms will have microbursts) that the probability of detection decreases slightly (from 100% to 96.4%) however, the false alarm rate improves dramatically, from 57.6% down to 32.5%. Further performance improvements are expected once MDPI is tuned for optimal performance after the summer 1995 data are analyzed. A complete AMU report on this past summer (June 1 to September 30, 1995) MDPI effort should be completed by December 1995, which will include September 1995 results not presented here.

5. MDPI Implementation

During the summer weather regime, early and late morning soundings are necessary to determine changes in the atmosphere that could affect forecasts of thunderstorm activity and their potential severity. Using profiles of θ_e, a forecaster should be able to differentiate between environments conducive for wet microburst and non-microburst days.

The 45th WS formally requested the AMU to develop a means of providing the forecaster a display of the θ_e profile and MDPI threshold index using the McIDAS (Man computer Interactive Data Access System) weather system (Adang 1995). The MDPI would be based on the observed vertical θ_e range (near surface θ_e - the observed minimum θ_e aloft) divided by the threshold critical value of 30° K.

The AMU, using a set of utilities in McIDAS, developed a program that automatically computes the equivalent potential temperature for each level when a new CCAS rawinsonde data are received. Finally, the program displays to the duty forecaster a current θ_e profile and previous and current MDPI threshold values (Figure 4).

The 45th WS also instituted a new level of microburst potential support operations. Beginning with the early morning CCAS rawinsonde and computed MDPI index, the forecaster determines the potential for thunderstorm development, the timing of the thunderstorm occurrence, and the microburst threat. This is then briefed to the support staff and additional personnel tasking would be assigned if needed to handle the increased workload.

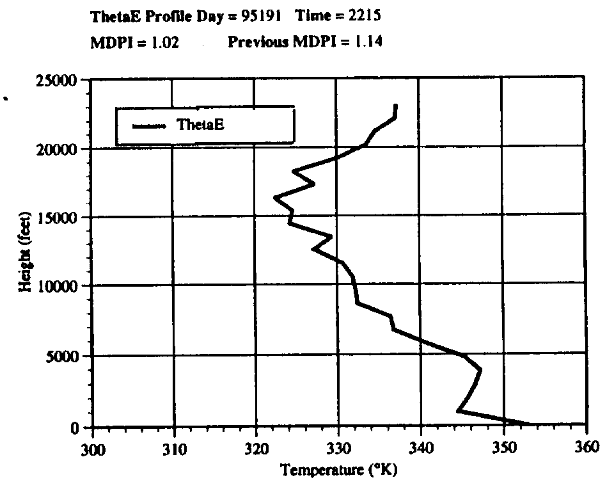

Figure 4. Example of McIDAS output of thermodynamic profile of equivalent potential temperature for May 1, 1995.

Additional nowcasting (< 30 minutes) techniques (Atkins and Wakimoto 1991; Eilts and Oakland 1989; Isaminger 1988) were also developed for the WSR-88D Doppler radar. The forecaster monitors storms for the following:

- High dBZ and VIL indicating heavy precipitation,
- A precipitation core of 55 dBZ reaching the MDPI's level of minimum θ_e,
- A descending precipitation core and/or divergent storm top,
- Convergence at the storm's mid-levels (especially near minimum θ_e), and
- Storms possessing rotation.

Another nowcasting technique was to monitor for secondary convection by observing the following:

- Sea breeze movement and hot spots and
- Colliding or intersecting convergent boundaries.

6. FUTURE PLANS

A separate McIDAS routine is being tested which calculates and displays to the duty forecaster the

Wind INDEX (WINDEX) gust value (McCann 1994). WINDEX calculates a potential surface gust strength. This program can be run hourly to update the surface based data in the program's calculations. The program that calculates the WINDEX value displays a θ_e profile along with two WINDEX values, one based on the latest rawinsonde data and a second WINDEX value based on the rawinsonde data and most recent surface observation.

The MDPI profile and WINDEX value are new tools to be used to alert the KSC/CCAS community of the potential of microburst winds and increase the forecaster's vigilance for nowcasting signatures. After this summer's effort, the 45th WS and AMU will tune the MDPI and incorporate WINDEX into the routine 45th WS displays. Potential also exists to incorporate the MDPI and WINDEX routines to the AMU's mesoscale model products currently under evaluation. This would allow the forecaster to view a forecast skew-t and display forecast MDPI and WINDEX values out to 24 hours.

7. SUMMARY

This paper reviewed the new 45th WS microburst forecasting and detection efforts in support of ground and launch operations at KSC and CCAS in collaboration with the AMU.

An unforecasted wind event on August 16, 1994 of 33.5 m s^{-1} (65 knots) at the SLF raised the concern of microburst detection and forecasting. The AMU researched and analyzed the downburst wind event and determined it was a wet microburst event. A program was developed for operational use on the McIDAS weather system to analyze, compute and display a equivalent potential temperature profile and MDPI index. The 45th WS developed a concept of operations that alerts the duty forecaster and staff of potential microburst days. These notification procedures also include all supported operations on the Eastern Range.

The AMU and 45th WS will continue to work together in further analyzing the data to tune the MDPI for optimal wet microburst forecasting and support to the 45th WS customers.

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